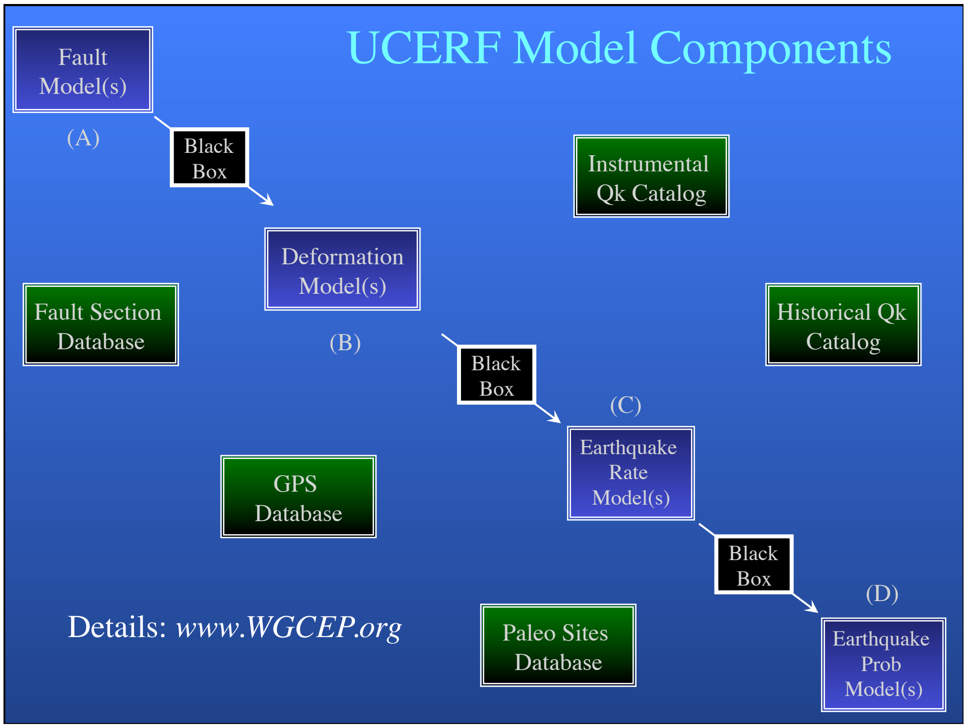
Fault and Deformation Models and Development of Earthquake Rate Models on "A" faults for the Working Group on California Earthquake Probabilities

Riverside, CA
October 17, 2006

WGCEP Development of a Uniform California Earthquake Rupture Forecast (UCERF)

Fault Model(s)
(A)
Black Box
Deformation Model(s)
(B)
Black Box
(C)
Earthquake Rate Model(s)
Black Box
(D)
Earthquake Prob Model(s)

Details: *www.WGCEP.org*



Fault Section Database

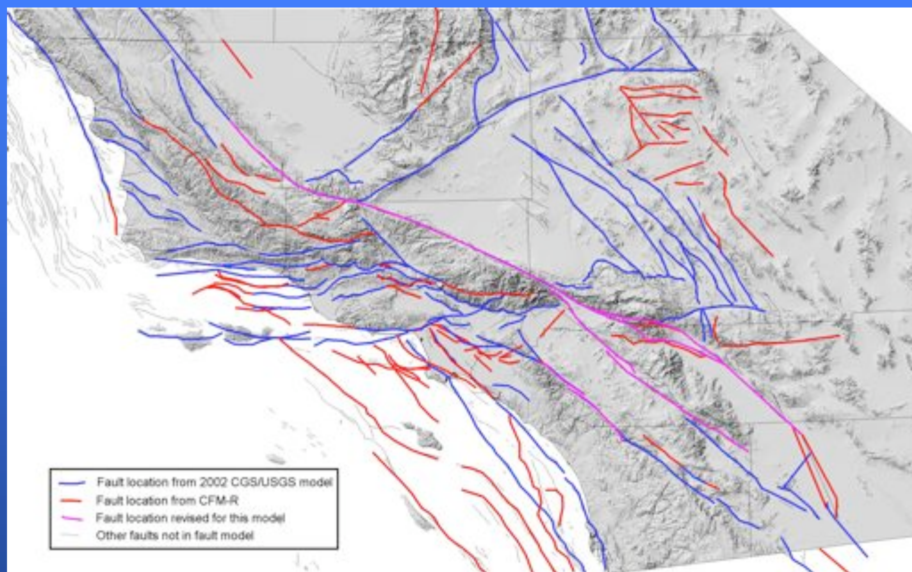
- fault location and seismic slip parameters to define fault and deformation models
  - Fault section name
  - fault trace (list of latitudes and longitudes)
  - average dip estimate
  - average upper seismogenic depth estimate
  - average lower seismogenic depth estimate
  - average long-term slip-rate estimate
  - average aseismic-slip-factor estimate
  - average rake estimate

Fault Models

- complete listing of all unique fault sections

Deformation Models

- complete fault model with unique, internally consistent slip rates



Fault geometry updates from CFM (includes revised top and bottom depths for all faults in CFM area)

A fault

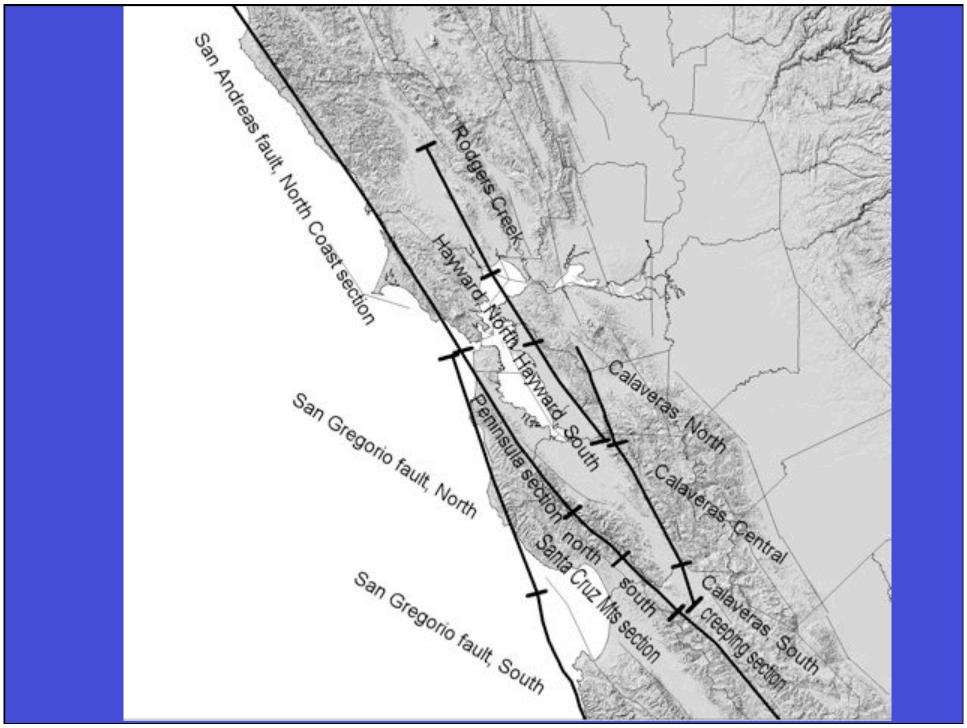
Major fault with high slip rates and sufficient data on slip rates, timing of past events, and slip per event that detailed models of fault zone behavior can be constructed

B fault

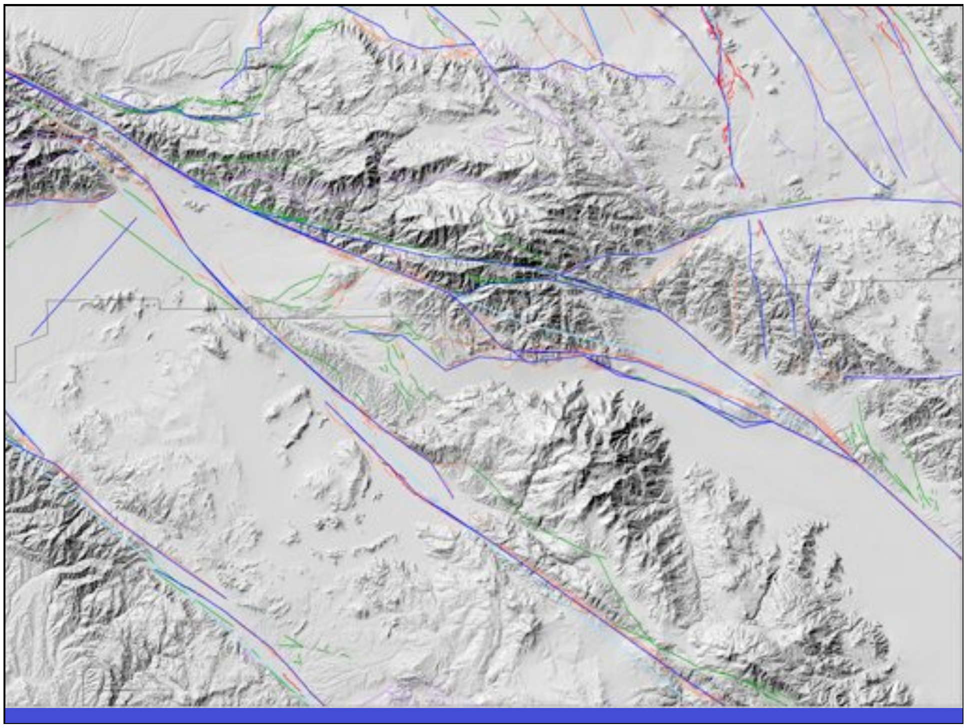
Faults that have significant slip rates but inadequate data on displacement or timing of past earthquakes to constrain detailed fault models

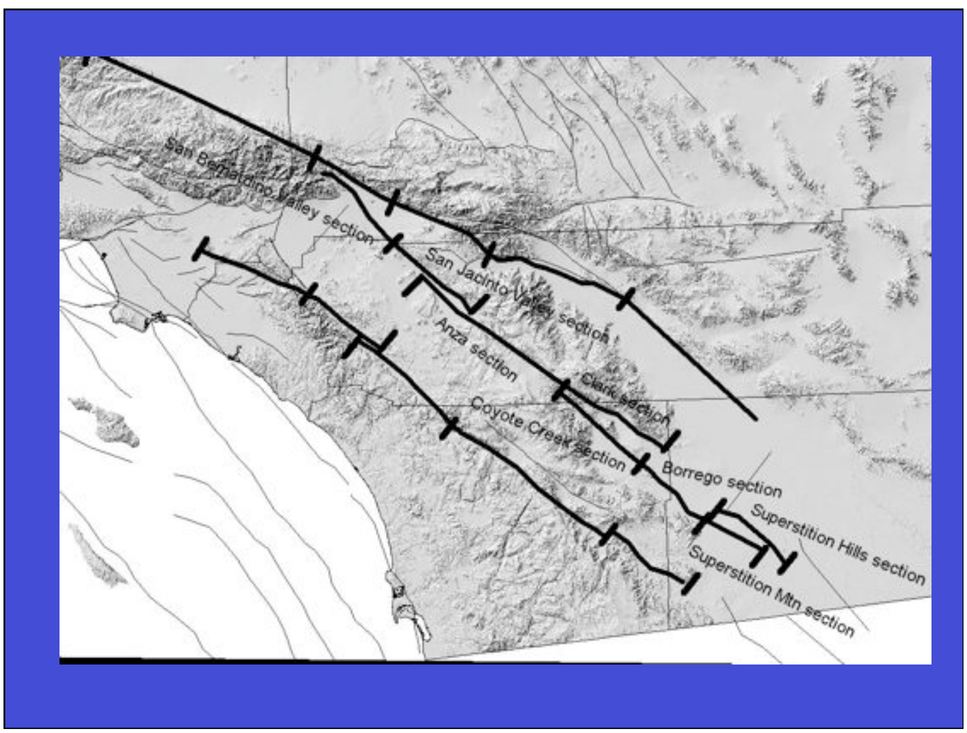
C fault

Zone of distributed shear with defined slip rate from geodetic and plate model where earthquakes may occur on recognized or unrecognized faults.


San Andreas fault, North Coast section
Rodgers Creek
Hayward, North
Hayward, South
Calaveras, North
Calaveras, Central
Calaveras, South
creeping section
San Gregorio fault, North
Peninsula section
north
south
Santa Cruz Mts section
San Gregorio fault, South


Parkfield section
Cholame section
Carrizo section
Big Bend section
Mojave, north section
Mojave, south section
San Bernardino, north section
San Bernardino, south section
San Gorgonio-Garnet Hill section
Coachella section




San Bernardino Valley section
San Jacinto Valley section
Anza section
Clark section
Coyote Creek section
Borrego section
Superstition Hills section
Superstition Mtn section

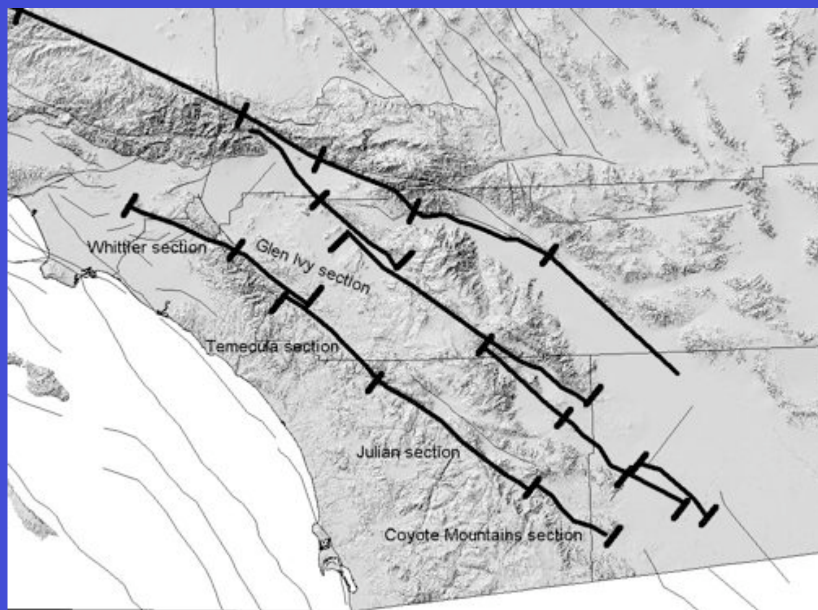


Table 1. Fault section database parameters, including source of trace and slip rate information

Fault Section Name	model	Source of fault trace	rake	dip	dip direction	slip rate	slip rate error	top depth	bottom depth	Details of slip rate, black from 1996 model, red from 2002 model, blue from 2006
Type A faults										
San Andreas (Offshore)		2002	180	90	n/a	24	3	0	11	Slip rate based on Niemi and Hall (1992) and Prentice, et al., (1991). WG99/WG02 source parameters used in 2002.
San Andreas (North Coast)		2002	180	90	n/a	24	3	0	11	Slip rate based on Niemi and Hall (1992) and Prentice, et al., (1991). WG99/WG02 source parameters used in 2002.
San Andreas (Peninsula)		2002	180	90	n/a	17	4	0	13	WG99/WG02 source parameters used in 2002.
San Andreas (Santa Cruz Mtn No)		WGCEP 2006	180	90	n/a	17	4	0	15	WG99/WG02 source parameters used in 2002 for Santa Cruz Mtn section. Section split in 2006 to accommodate potential for more frequent earthquakes on southern part of section at Arano Flat (T. Fumal personal communication, 2006).
San Andreas (Santa Cruz Mtn So)		WGCEP 2006	180	90	n/a	17	4	0	15	WG99/WG02 source parameters used in 2002 for Santa Cruz Mtn section. Section split in 2006 to accommodate potential for more frequent earthquakes on southern part of section at Arano Flat (T. Fumal personal communication, 2006).
San Andreas (Creeping Segment)		2002	180	90	n/a	34	5	0	12	WG99/WG02 source parameters used in 2002.
San Andreas (Parkfield)		CFM-R	180	90	n/a	34	5	0	10.2	Slip rate reported by WGCEP (1995)
San Andreas (Cholame)		WGCEP 2006	180	90	n/a	34	5	0	12	Slip rate based on analogy with Carrizo segment. South section boundary moved to north end of Carrizo Plain.
San Andreas (Carrizo)		WGCEP 2006	180	90	n/a	34	3	0	15.1	Slip rate based on Sieh and Jahns (1984)
San Andreas (Big Bend)		WGCEP 2006	180	90	n/a	34	3	0	15.1	Slip rate based on Sieh and Jahns (1984). Section split from 2002 Carrizo section because of difference in trend and possible differences in slip distribution in 1857 and 1812 earthquakes.
San Andreas (Mojave N)		WGCEP 2006	180	90	n/a	29	7	0	15.1	Slip rate based on Sieh (1984), Salyards et al. (1992), and WGCEP (1995) Section split from 2002 Mojave section because differences in slip distribution in 1812 earthquake.
San Andreas (Mojave S)		WGCEP 2006	180	90	n/a	29	7	0	13.1	Slip rate based on Sieh (1984), Salyards et al. (1992), and WGCEP (1995) Section split from 2002 Mojave section because differences in slip distribution in 1812 earthquake.
San Andreas (San Bernardino N)		WGCEP 2006	180	90	n/a	17	6	0	12.8	Slip rate reported by Weldon and Sieh (1985) Section split from 2002 San Bernardino section at intersection of north branch (Mill Creek fault).
San Andreas (San Bernardino S)		WGCEP 2006	180	90	n/a	6	4	0	12.8	Slip rate reported by Weldon and Sieh (1985) Section split from 2002 San Bernardino section at intersection of north branch (Mill Creek fault). Slip rate reduced 8 mm/yr from San Bernardino North section to accommodate 6 mm/yr slip transfer to San Jacinto fault and 2 mm/yr slip on north branch.
San Andreas (San Gorgonio Pass - Garnet Hill)		WGCEP 2006	180	58	N	6	4	0	16.4	Slip rate reported by Weldon and Sieh (1985). Slip assumed equal to San Bernardino S section.
San Andreas (Coachella)		2002	180	90	n/a	19	5	0	11.1	Slip rate based on Sieh and Williams (1990), Sieh (1986), Keller et al. (1982); Bronkowski (1981) Section modified from 2002 by moving northern end point to intersection of North Branch (Mill Creek fault) with Banning section.
Imperial		CFM-R	180	82	NE	20	5	0	14.6	Slip rate based on study by Thomas and Rockwell (1996).
San Jacinto (San Bernardino)		WGCEP	180	90	n/a	12	6	0	16.1	Slip rate reported by WGCEP (1995). Southern end of section

Fault revised since 2002 model | Fault added since 2002 model

Table 1. Fault section database parameters, including source of trace and slip rate information

Fault Section Name	model	Source of fault trace	rake	dip	dip direction	slip rate	slip rate error	top depth	bottom depth	Details of slip rate, black from 1996 model, red from 2002 model, blue from 2006
		2006								moved to south margin of San Bernardino valley, inferred change from compressional to extensional component of motion.
San Jacinto (San Jacinto Valley)		WGCEP 2006	180	90	n/a	18	6	0	18.5	Slip rate reported by WGCEP (1995). Slip rate changed to high end of range from geologic studies for consistency with geodetic studies.
San Jacinto (San Jacinto Valley, stepover)		WGCEP 2006	180	90	n/a	9	3	0	16.8	Slip rate reported by WGCEP (1995). Slip rate on zone distributed equally between parallel faults on either side of stepover.
San Jacinto (Anza, stepover)		WGCEP 2006	180	90	n/a	9	3	0	16.8	Slip rate reported by WGCEP (1995). Slip rate on zone distributed equally between parallel faults on either side of stepover.
San Jacinto (Anza)		WGCEP 2006	180	90	n/a	18	6	0	16.8	Slip rate reported by WGCEP (1995). Slip rate changed to high end of range from geologic studies for consistency with geodetic studies.
San Jacinto (Clark)		WGCEP 2006	180	90	n/a	14	6	0	16.8	Slip rate reported by WGCEP (1995). Slip rate changed to high end of range from geologic studies for consistency with geodetic studies, then reduced by slip on parallel Coyote Creek section.
San Jacinto (Coyote Creek)		CFM-R	180	90	n/a	4	2	0	15.9	Slip rate reported by WGCEP (1995).
San Jacinto (Borrego)		CFM-R	180	90	n/a	4	2	0	13.1	Slip rate reported by WGCEP (1995).
Superstition Hills		CFM-R	180	90	n/a	4	2	0	12.6	Slip rate reported by WGCEP (1995).
Superstition Mountain		CFM-R	180	90	n/a	5	3	0	12.4	Slip rate based on Gurrola and Rockwell (1996)
Whittier alt 1	Chino cuts Whittier	CFM-R	150	70	NE	2.5	1	0	12.4	Slip rate based on Rockwell et al. (1990); Gath et al. (1992) description of offset drainage.
Whittier alt 2	Whittier cuts Chino	CFM-R	150	75	NE	2.5	1	0	14.1	Slip rate based on Rockwell et al. (1990); Gath et al. (1992) description of offset drainage.
Elsinore (Glen Ivy)		CFM-R	180	80	SW	5	2	0	13.3	Reported slip rates vary from 3.0-7.2 (Millman and Rockwell, 1986)
Elsinore (Glen Ivy stepover)		WGCEP 2006	180	80	SW	2.5	2	0	13.3	Reported slip rates vary from 3.0-7.2 (Millman and Rockwell, 1986) Slip rate on zone distributed equally between parallel faults on either side of stepover.
Elsinore (Temecula stepover)		WGCEP 2006	180	80	SW	2.5	2	0	13.3	Reported slip rates vary from 3.0-7.2 (Millman and Rockwell, 1986) Slip rate on zone distributed equally between parallel faults on either side of stepover.
Elsinore (Temecula)		WGCEP 2006	180	88	NE	5	2	0	14.2	Slip rate reported by WGCEP (1995). Trace modified to follow trace of Wildomar fault.
Elsinore (Julian)		CFM-R	180	84	NE	3	1	0	18.8	Slip rate reported by WGCEP (1995). Slip rate reduced by slip on parallel Earthquake Valley fault.
Elsinore (Coyote Mountain)		CFM-R	180	82	NE	3	1	0	13.2	Slip rate reported by WGCEP (1995). Slip rate from Rockwell, 1990.
Laguna Salada		CFM-R	180	90	n/a	3.5	1.5	0	13.3	Slip rate reported by Mueller and Rockwell (1995)
Hayward (Northern)		2002	180	90	n/a	9	2	0	12	Well constrained slip rate for southern segment reported by Lienkaemper, et al. (1995) and Lienkaemper and Borchardt (1996) WG99/WG02 source parameters used in 2002.
Hayward (Southern)		2002	180	90	n/a	9	2	0	12	Well constrained slip rate for southern segment reported by Lienkaemper, et al. (1995) and Lienkaemper and Borchardt (1996) WG99/WG02 source parameters used in 2002.
Rodgers Creek		2002	180	90	n/a	9	2	0	12	Slip rate is composite of slip rate reported by Schwartz, et al. (1992) and slip rate from Hayward fault (Lienkaemper and Borchardt, 1996) WG99/WG02 source parameters used in 2002.

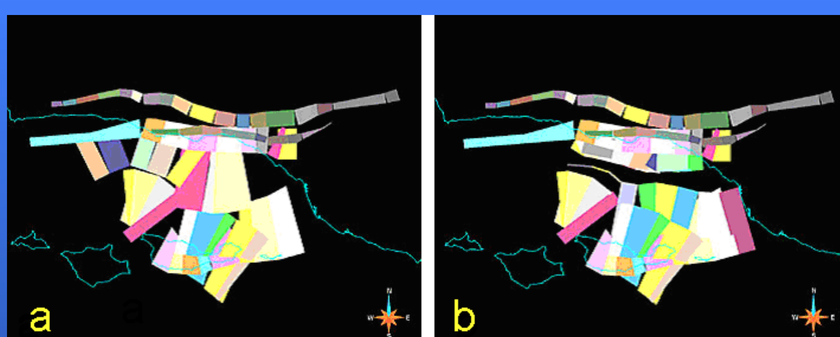


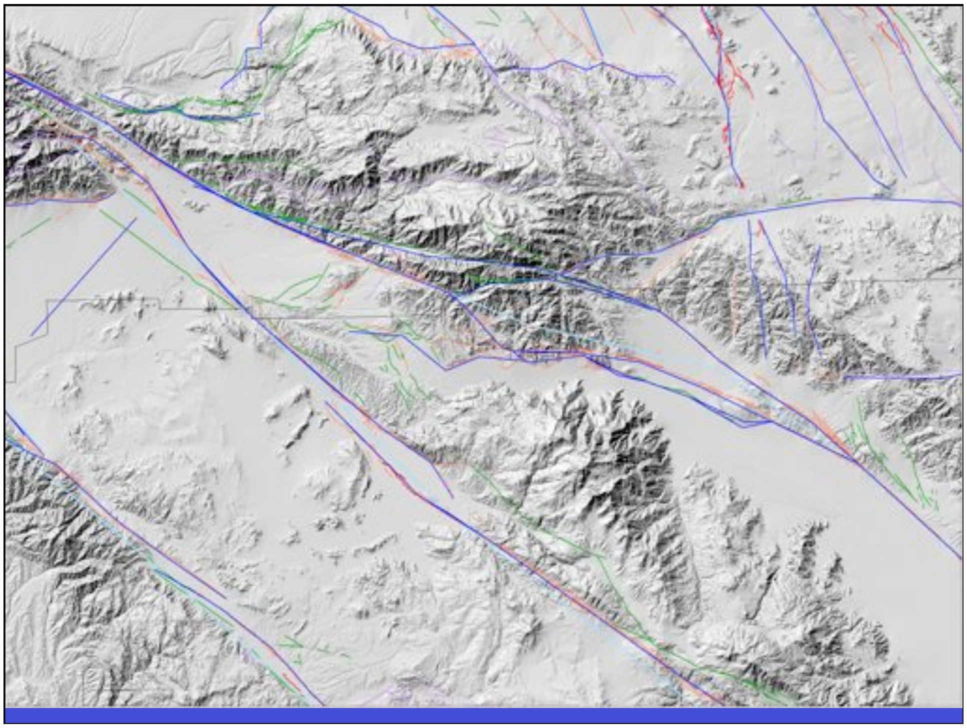
Table 1, Fault section database parameters, including source of trace and slip rate information

Fault Section Name	model	Source of fault trace	rake	dip	dip direction	slip rate	slip rate error	top depth	bottom depth	Details of slip rate, black from 1996 model, red from 2002 model, blue from 2006
Western Transverse Ranges and Santa Barbara Channel										
Channel Islands Thrust		CFM-R	90	21	N	1.5	1	7.4	14.7	
Channel Islands Western Deep Ramp		CFM-R	90	21	SW			4.8	12.5	
Mission Ridge-Arroyo Parida-Santa Ana		2002	90	70	S	0.4	0.2	0	7.6	Minimum dip slip rate based on Rockwell, et al (1984). Assumption that half of 65 km length ruptures. Total length includes More Ranch fault
North Channel	CFM Santa Barbara alt 2	CFM-R	90	26	N	1	1			(replaces 2002 North Channel Slope fault in alt 2)
North Channel Slope		2002	90	26	N	2	2	10	20	
Oak Ridge (blind thrust offshore)		2002	90	30	S	3	3	0	7.8	
Oak Ridge offshore	CFM Santa Barbara alt 2	CFM-R	90	32	S	3	3	0	7.9	(replaces 2002 Oak Ridge (blind thrust offshore) in alt 2)
Oak Ridge offshore, west extension	CFM Santa Barbara alt 2	CFM-R	90	78	S	3	3	0.4	3.1	(replaces 2002 Oak Ridge (blind thrust offshore) in alt 2)
Pitas Point (Lower) Montalvo	CFM Santa Barbara alt 1	CFM-R	90	16	N	3	3	0.4	12.7	(replaces 2002 Oak Ridge (blind thrust offshore) in alt 1)
Pitas Point (Lower), west	CFM Santa Barbara alt 1	CFM-R	90	13	N	3	3	1.5	8.8	(replaces 2005 Oak Ridge (blind thrust offshore) in alt 1)
Pitas Point (Upper)	CFM Santa Barbara alt 2	CFM-R	90	42	N	1	1	1.4	10	(replaces 2002 North Channel Slope fault in alt 2)
Red Mountain		CFM-R	90	56	N	2	1	0	14.1	Slip rate based on summation of two strands of Red Mtn. flt at Punta Gorda reported in Clark, et al., 1984).
Santa Cruz Island		CFM-R	30	90	n/a	1	0.5	0	13.3	Moderately constrained Qt. slip rate (0.75mm/yr) based on offset streams incised into Stage 11 (?) terrace (Pinter, et al., 1995).
Santa Rosa Island		CFM-R	30	90	n/a	1	0.5	0	8.7	Moderately constrained Qt. slip rate (1mm/yr) based on offset incised stream channels (Colson et al., 1995).
Santa Ynez (East)		CFM-R	0	70	S	2	1	0	13.3	Slip rate is preferred left-lateral, based on offset stream channel reported by Darrow and Sylvester (1984).
Santa Ynez (West)		CFM-R	0	70	S	2	1	0	9.2	Slip rate is preferred left-lateral, based on offset stream channel reported by Darrow and Sylvester (1984).
South Cuyama		CFM-R		33	SW		0	0	5.6	

Development of Deformation Models

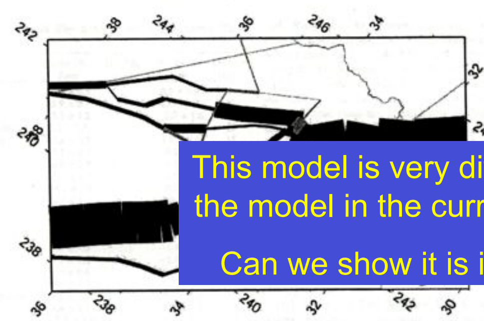
- Should consider latest geologic slip rate estimates
- Slip rates for model should sum to plate rate
- Seismic moment should be conserved along a fault zone
- Geodetic rates can be considered (though they are not explicitly modeled in this version)

- Our goal is a complete, kinematically consistent model of fault rates throughout California



Very little slip on San Andreas

MEADE AND HAGER: SOUTHERN CALIFORNIA BLOCK MODELS



This model is very different from the model in the current NSHM-

Can we show it is incorrect?

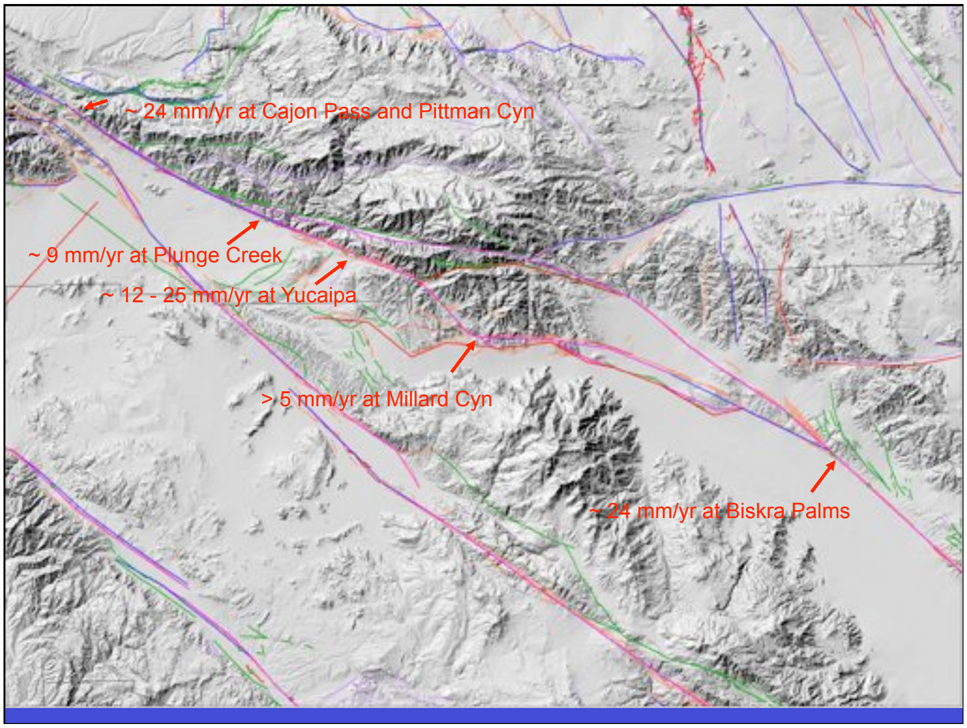
Figure 12. The estimated strike-slip rates from our preferred block model. Black and gray lines indicate right- and left-lateral motion, respectively. Wider lines indicate faster slip rates. The thickest lines represent the SAF and SJF where ~70% of the relative plate motion is accommodated.

Table 2. Selected Fault Slip Rates From Our Preferred Block Model*

Fault Name	Strike-Slip Rate	Dip-Slip Rate	Tensile-Slip Rate	Locking Depth
SAF (Parkfield)	36.0 ± 0.5	...	0.1 ± 0.4	1
SAF (Carrizo)	35.9 ± 0.7	...	2.6 ± 0.4	22
SAF (Mojave)	14.3 ± 1.2	...	−2.7 ± 1.6	15
SAF (San Bernadino)	5.1 ± 1.5	...	1.0 ± 1.7	15
SAF (Salton Sea)	23.3 ± 0.5	...	1.5 ± 0.6	15
SAF (Imperial)	36.1 ± 0.7	...	−9.6 ± 0.5	0
SAF (Cerro Prieto)	40.0 ± 1.5	...	−6.5 ± 0.5	15
Eureka Peak	21.3 ± 1.6	...	−4.5 ± 1.0	5
Pinto Mountain	−9.4 ± 0.9	...	−9.2 ± 1.0	10
San Jacinto	11.9 ± 1.2	...	0.0 ± 0.7	10
Elsinore	2.7 ± 0.6	...	−0.6 ± 0.7	15
Rose Canyon	0.2 ± 2.5	...	0.8 ± 2.0	15
Oceanside	1.9 ± 3.2	...	2.6 ± 2.8	15
Coronado Bank	5.0 ± 3.0	...	−1.4 ± 1.9	15
San Clemente	3.1 ± 1.6	...	−1.9 ± 0.9	15
Hosgri	3.9 ± 0.6	...	0.7 ± 0.6	15
Agua Blanca	9.1 ± 2.7	...	0.7 ± 1.6	15
Newport – Inglewood	0.8 ± 1.6	...	0.3 ± 1.3	15
[illegible]	3.4 ± 1.4	...	3.1 ± 1.5	15
[illegible]	−2.3 ± 1.0	...	0.7 ± 1.7	15
[illegible]	0.1 ± 1.4	...	−4.0 ± 0.8	15
[illegible]	−0.2 ± 1.1	4.2 ± 0.9	...	15
[illegible]	−4.0 ± 1.3	10.0 ± 1.5	...	15
[illegible]	−2.4 ± 1.1	−1.4 ± 2.3	...	15
[illegible]tains	−2.4 ± 1.1	−0.2 ± 2.2	...	15
[illegible]	3.1 ± 1.2	9.3 ± 2.4	...	15
[illegible]	3.2 ± 1.5	3.9 ± 2.4	...	15
[illegible]	3.1 ± 1.3	11.8 ± 2.5	...	15
[illegible]	2.1 ± 1.3	4.2 ± 2.1	...	5
[illegible]	−8.5 ± 1.4	8.0 ± 2.2	...	5
White Wolf	1.3 ± 1.2	4.6 ± 1.7	...	15
North Frontal	−0.8 ± 1.7	3.0 ± 3.0	...	10
Coastal Ranges Split	5.5 ± 1.5	...	−2.3 ± 1.0	15
San Gabriel	3.8 ± 2.2	...	1.4 ± 2.0	15
Garlock (west)	−3.2 ± 1.5	...	4.7 ± 1.5	15
Garlock (central)	−1.8 ± 1.5	...	−0.2 ± 1.4	15
Garlock (east)	−1.1 ± 1.9	...	−5.2 ± 1.4	10
Blackwater-Landers	1.9 ± 0.6	...	0.1 ± 1.1	5
Helendale	2.2 ± 1.2	...	−2.1 ± 1.1	10
Goldstone	13.4 ± 1.0	...	0.0 ± 1.4	10
Eastern Mojave	−2.5 ± 0.8	...	−0.8 ± 0.8	10
Nevada Split	−0.9 ± 0.6	...	−2.6 ± 0.6	10
Airport Lake	7.3 ± 1.1	...	0.9 ± 1.5	10
Owens Valley	3.5 ± 0.9	...	−0.5 ± 0.8	10
Panamint Valley	3.1 ± 1.3	...	−3.3 ± 1.2	10
Death Valley	2.4 ± 1.2	...	−0.7 ± 0.9	10
Fish Lake	6.0 ± 2.1	...	−1.4 ± 1.0	10

*All rates are given in mm/yr. Positive and negative strike-slip rates give right- and left-lateral motion, respectively. Positive and negative dip-slip rates give thrust and normal motion, respectively. Positive and negative tensile-slip rates give closing and opening motion, respectively. In all cases, the slip rate is evaluated at the middle of the segment. SAF is an abbreviation for the San Andreas fault.

Large slip on Eastern California Shear Zone



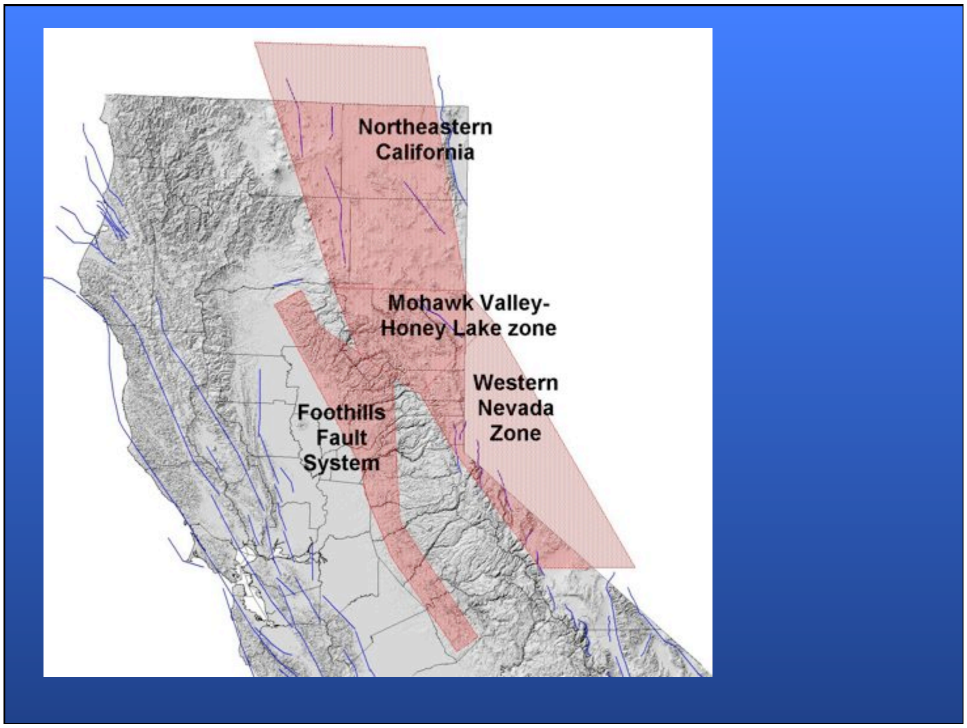
If the slip that we previously modeled on the San Andreas fault doesn't go through the San Gorgonio Pass, where does it go?

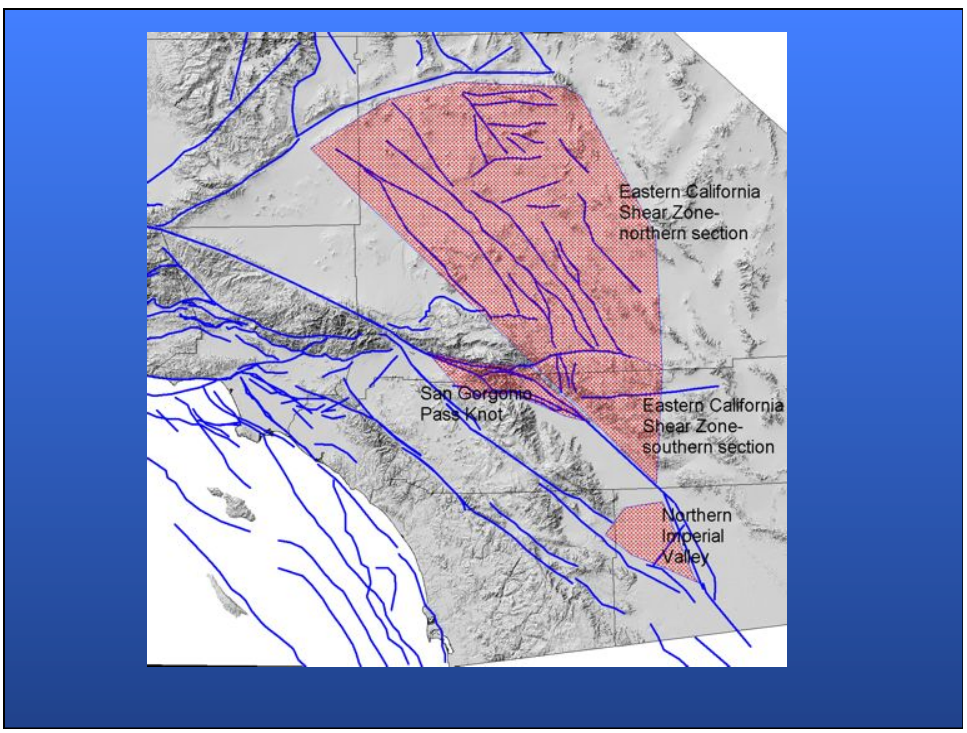
How much slip is on the San Jacinto?
•Rockwell suggests ~ 16 mm/yr at Hog Lake
•Janecke suggests ~ 20 mm/yr in last MY on southern San Jacinto

Need models with higher slip on the San Jacinto

How much slip is transferred to the Eastern California Shear Zone?
•Geodetic models suggest 12-16 mm/yr
•Western Great Basin faults total ~ 8 mm/yr
•Recent very preliminary geologic studies by Oskin suggest ~ 6 mm on faults

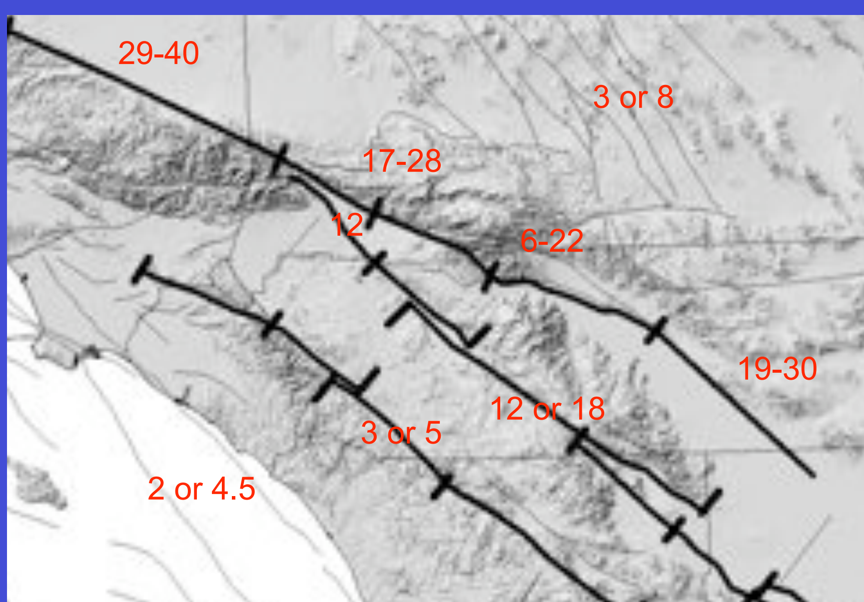
Need models with higher slip in Eastern California Shear Zone


Northeastern
California
Mohawk Valley-
Honey Lake zone
Western
Nevada
Zone
Foothills
Fault
System


Eastern California
Shear Zone-
northern section
San Gorgonio
Pass Knot
Eastern California
Shear Zone-
southern section
Northern
Imperial
Valley

2.1 Equal San Jacinto & San Andreas w 8 on ECSZ	Slip Rate	Slip Rate Error	2.2 Traditional San Andreas dominant w 8 on ECSZ	Slip Rate	Slip Rate Error	2.3 Equal San Jacinto & San Andreas, low ECSZ	Slip Rate	Slip Rate Error	2.4 Traditional San Andreas dominant, low ECSZ	Slip Rate	Slip Rate Error
Preliminary Weight		35%	Preliminary Weight	20%		Preliminary Weight	10%		Preliminary Weight		10%
SA Mojave	29	7	SA Mojave	29	7	SA Mojave	34	7	SA Mojave	34	7
SA San Bernardino N	17	5	SA San Bernardino N	17	6	SA San Bernardino N	24	5	SA San Bernardino N	22	6
SA San Bernardino S and Garnet Hill	6	2	SA San Bernardino S and Garnet Hill	9	3	SA San Bernardino S and Garnet Hill	8	3	SA San Bernardino S and Garnet Hill	11	5
San Gorgonio Pass Knot	5	2	San Gorgonio Pass Knot	8	3	San Gorgonio Pass Knot	8	3	San Gorgonio Pass Knot	11	5
SA Coachella	19	5	SA Coachella	25	5	SA Coachella	19	5	SA Coachella	25	5
SJ San Bernardino Valley	12	6	SJ San Bernardino Valley	12	6	SJ San Bernardino Valley	12	6	SJ San Bernardino Valley	12	6
SJ San Jacinto Valley & Anza	18	6	SJ San Jacinto Valley & Anza	12	6	SJ San Jacinto Valley & Anza	18	6	SJ San Jacinto Valley & Anza	12	6
ECSZ (aggregate)	8	4	ECSZ (aggregate)	8	4	ECSZ (aggregate)	3	2	ECSZ (aggregate)	3	2
Elsinore	5	2	Elsinore	5	2	Elsinore	5	2	Elsinore	5	2
NI	1.5	0.5	NI	1.5	0.5	NI	1.5	0.5	NI	1.5	0.5
Palos Verdes	3	1	Palos Verdes	3	1	Palos Verdes	3	1	Palos Verdes	3	1

2.5 High San Andreas and San Jacinto low ECSZ	Slip Rate	Slip Rate Error	2.6 High San Andreas and San Jacinto, low slip to w	Slip Rate	Slip Rate Error	2.7 High San Andreas, low San Jacinto, low slip to w	Slip Rate	Slip Rate Error	2.8 High San Andreas and San Jacinto, low slip ECSZ and to w	Slip Rate	Slip Rate Error
Preliminary Weight		10%	Preliminary Weight	5%		Preliminary Weight	5%		Preliminary Weight		5%
SA Mojave	39	7	SA Mojave	34	7	SA Mojave	34	7	SA Mojave	40	7
SA San Bernardino	27	6	SA San Bernardino	22	5	SA San Bernardino	22	5	SA San Bernardino	28	5
SA San Bernardino S and Garnet Hill	11	5	SA San Bernardino S and Garnet Hill	8	3	SA San Bernardino S and Garnet Hill	11	5	SA San Bernardino S and Garnet Hill	11	5
San Gorgonio Pass Knot	10	4	San Gorgonio Pass Knot	8	3	San Gorgonio Pass Knot	11	4	San Gorgonio Pass Knot	11	4
SA Coachella	24	5	SA Coachella	24	5	SA Coachella	30	5	SA Coachella	25	5
SJ San Bernardino Valley	12	6	SJ San Bernardino Valley	12	6	SJ San Bernardino Valley	12	6	SJ San Bernardino Valley	12	6
SJ San Jacinto Valley & Anza	18	6	SJ San Jacinto Valley & Anza	18	6	SJ San Jacinto Valley & Anza	12	6	SJ San Jacinto Valley & Anza	18	6
ECSZ (aggregate)	3	2	ECSZ (aggregate)	8	4	ECSZ (aggregate)	8	4	ECSZ (aggregate)	3	2
Elsinore	5	2	Elsinore	3	2	Elsinore	3	2	Elsinore	3	2
NI	1.5	0.5	NI	1	0.5	NI	1	0.5	NI	1	0.5
Palos Verdes	3	1	Palos Verdes	1	0.5	Palos Verdes	1	0.5	Palos Verdes	1	0.5



Development of earthquake rate models

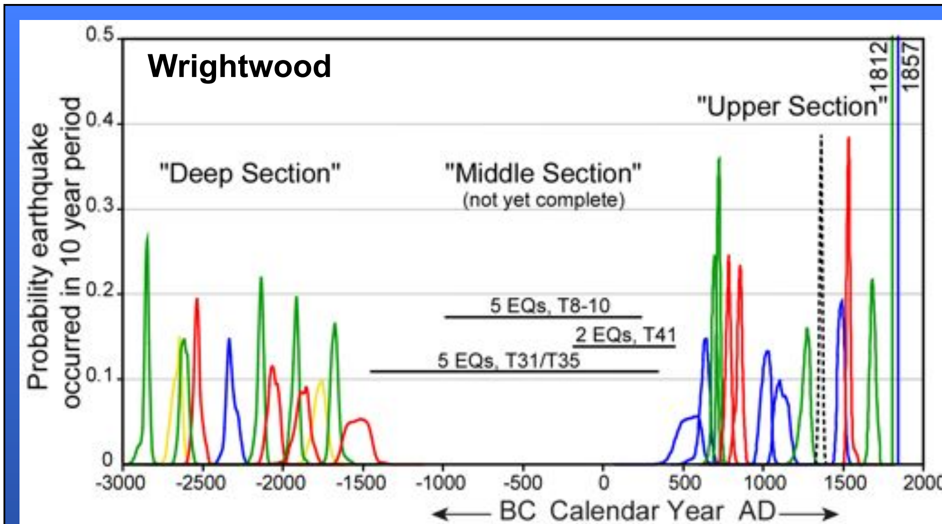
Earthquake rates depend on slip rates and are as consistent as possible with paleoseismic data.

All segments and combinations of segments have rates of earthquakes in three models

- Minimum earthquake rate model
- Maximum earthquake rate model
- Geologic insight model

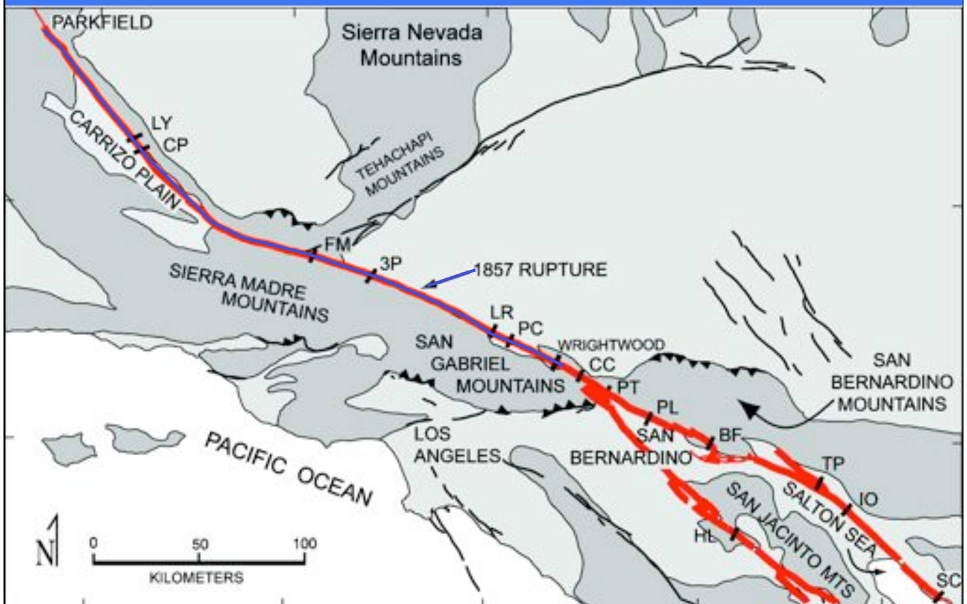
Southern San Andreas based on detailed numeric analysis by Weldon and Biasi

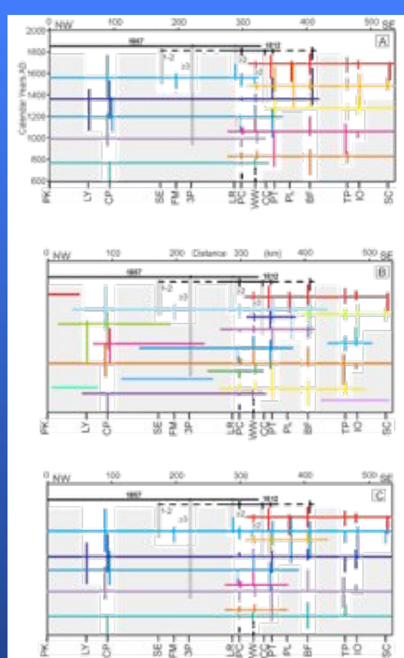
Other A-faults based on “hand-built” models due to sparse data



We start with the ages of a series of earthquakes, usually represented as probability density functions of age. There is great variability in the precision of the age control (width of peaks), the quality of the evidence identifying an event (colors, in the case), if the event seen in the trench was even an earthquake, and if so how large.

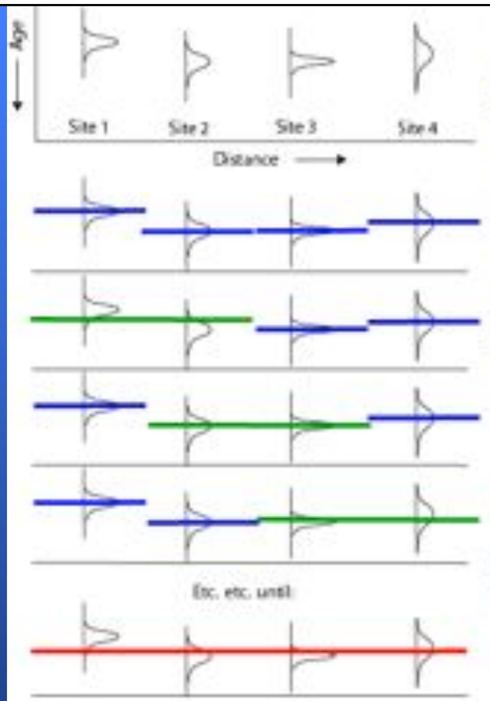
We need to combine data from many sites to define discrete ruptures.



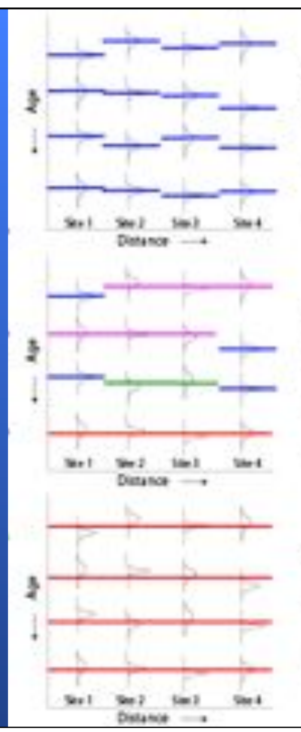


One way to combine sites is to make a space-time diagram with vertical bars representing the age ranges of earthquakes at all sites and then connect them by horizontal bars representing earthquakes.

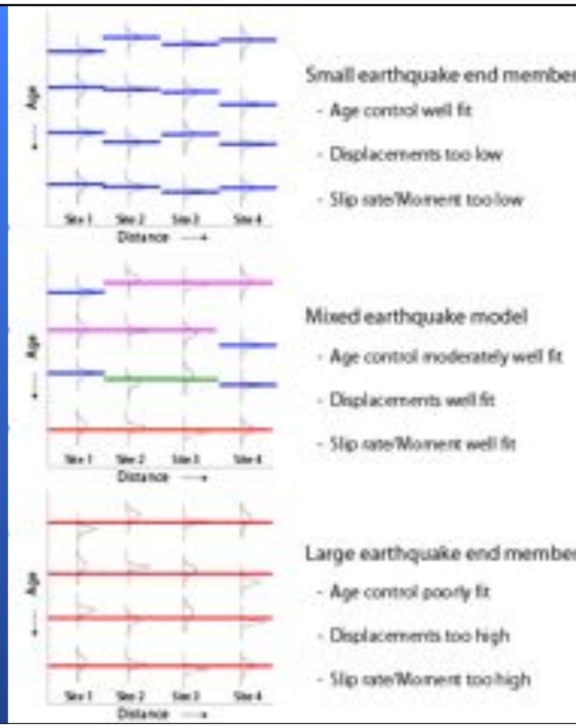
Obviously, the sites can be connected many different ways.

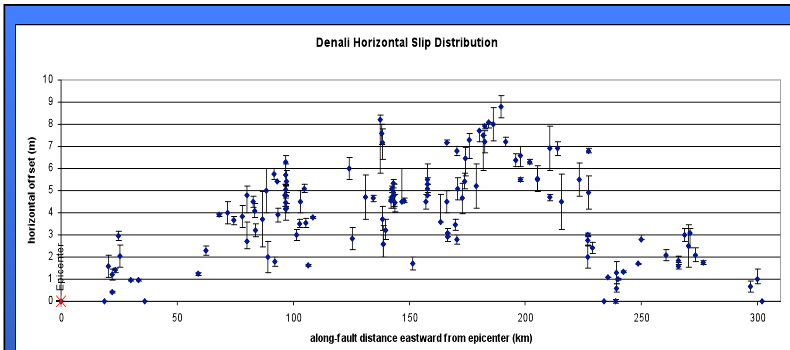


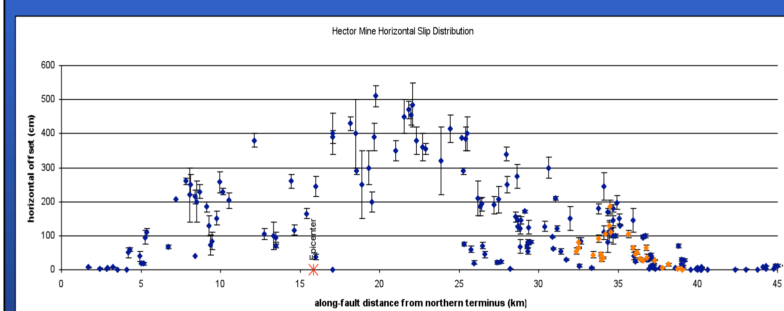
Overlapping pdfs from 4 sites can be correlated by progressively linking sites. These 4 paleoquakes can represent 4 different earthquakes (top), a single earthquake (bottom) and many different 2 to 3 earthquake combinations in between



Once we have all ruptures, we string them together to make "scenarios;" ie possible earthquake histories that describe the complete paleoseismic dataset. This is done by drawing randomly from our pool of ruptures, removing all other ruptures that share site events already chosen, choose again, etc. until all site data is used to make a possible history.

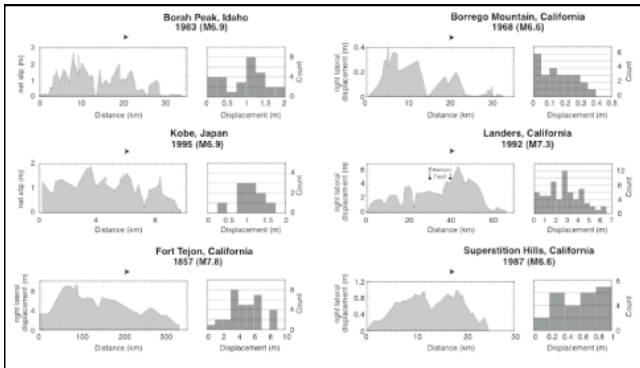




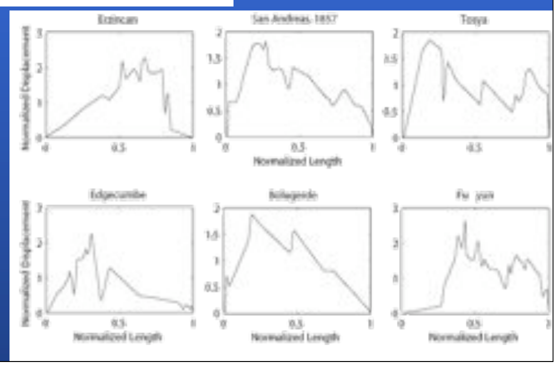


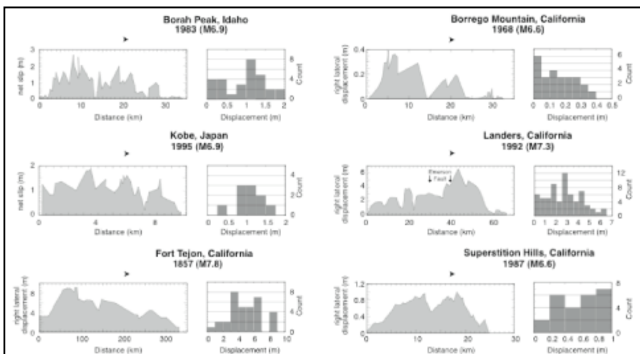
To quantify how well a scenario matches displacement or slip rate/ moment, we need to know what an earthquake's slip distribution looks like.

Here are two well studied examples, with very similar shapes despite being an order of magnitude different in length and offset.

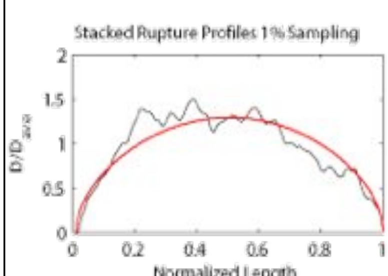


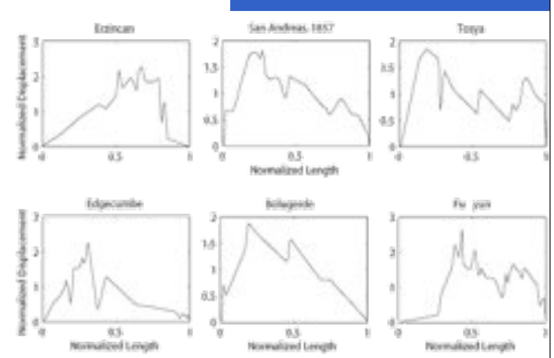
If we look at a lot of historical ruptures we find that they are very irregular, but generally taper towards each end and often have a high about 1/3 of the distance from one end.



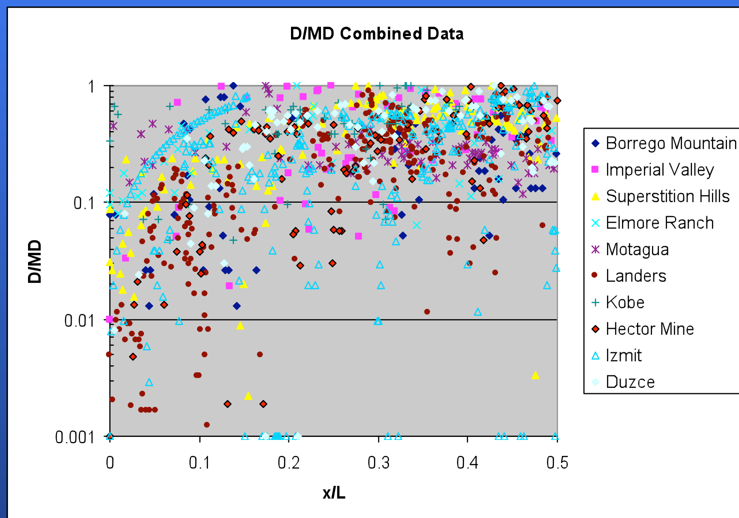


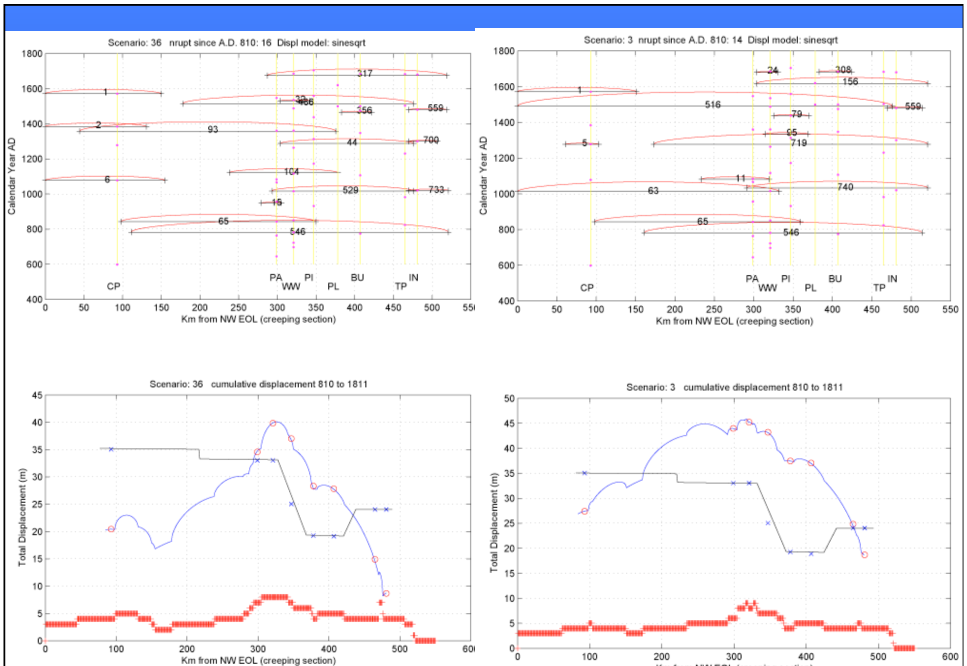
If we normalize and stack many historical ruptures we can find an average shape. We fit this shape with a square root of sine curve. Note that since rupture direction is left to right, there is some asymmetry; however, we rarely know the rupture direction for pre-historic quakes.

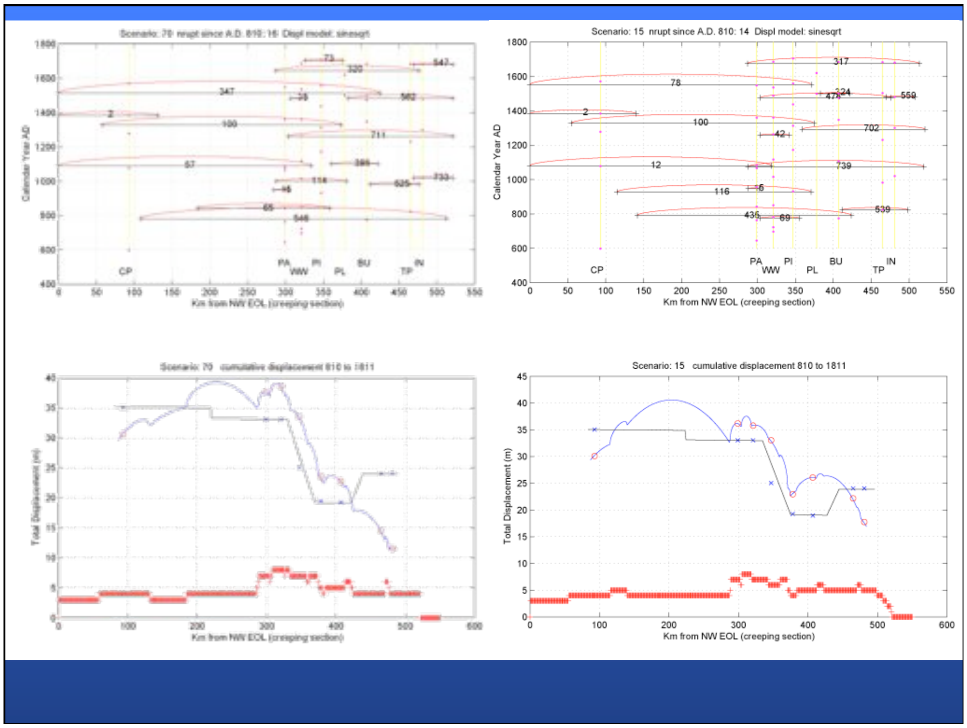


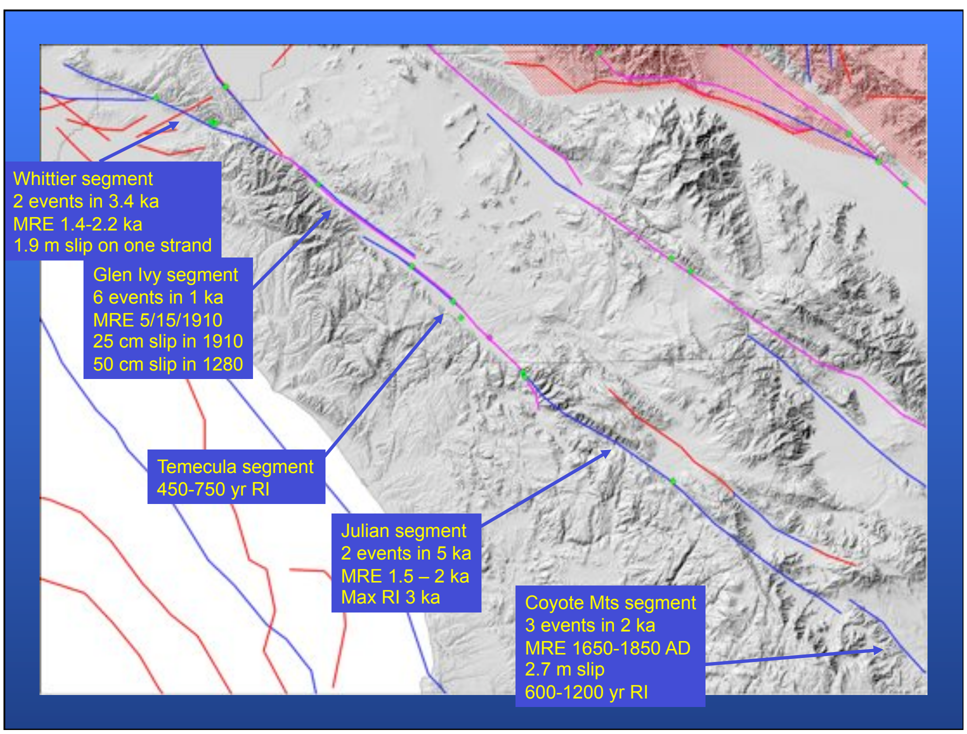


Principal faulting: Main trace displacement/maximum displacement along length of the rupture






Scenario: 15 nrupt since A.D. 810: 14 Displ model: sinesqrt
Calendar Year AD
Km from NW EOL (creeping section)
Scenario: 15 cumulative displacement 810 to 1811
Total Displacement (m)
Km from NW EOL (creeping section)


Whittier segment
2 events in 3.4 ka
MRE 1.4-2.2 ka
1.9 m slip on one strand
Glen Ivy segment
6 events in 1 ka
MRE 5/15/1910
25 cm slip in 1910
50 cm slip in 1280
Temecula segment
450-750 yr RI
Julian segment
2 events in 5 ka
MRE 1.5 – 2 ka
Max RI 3 ka
Coyote Mts segment
3 events in 2 ka
MRE 1650-1850 AD
2.7 m slip
600-1200 yr RI

Elsinore (segments: ECM Coyote Mtn, EJ Julian, ET Temecula, EGI Glen Ivy, EW Whittier)

Segment	Rate	RI Ave	RI low	RI high	SR assumed	SR low	SR high	SPE ave	SPE low	SPE high	Num events	Duration
EW	0.00072	1380	760	2000	2.5				1.9		2	3400
EGI	0.00300	333.333333			>5	5.5	5.90000	0.5	0.25	0.5	3	1000
ET	0.00167	600	450	750	5	1.5	7.00000	2.5-3				
EJ	0.00050	2000	1000	3000	3	2.5	3.00000	5+			2	6000
ECM	0.00107	933.333333	666.6666667	1200	3	2	3.50000	2.7			3	2000
Sections		**Rate**	**Numerical rate**	**AutoCalc from RI**	**total**	**total by segment**			**Diff from RawRI**			
maximum ruptures model- all segments independent												
EW		3/4000	0.00075	0.00072		EW	0.00072		0.00000			
EGI		12/4000	0.00300	0.00300		EGI	0.00300		0.00000			
ET		7/4000	0.00175	0.00167		ET	0.00167		0.00000			
EJ		2/4000	0.00050	0.00050		EJ	0.00050		0.00000			
ECM		4/4000	0.00100	0.00107	0.00696	ECM	0.00107		0.00000			
minimum ruptures model:												
ECM+EJ+ET+EGI+EW		2/4000	0.0005	0.00050		EW	0.00072		0.00000			
ECM		2/4000	0.0005	0.00057		EGI	0.00300		0.00000			
ET+EGI+EW		1/4000	0.00025	0.00022		ET	0.00167		0.00000			
ET+EGI		4/4000	0.001	0.00094		EJ	0.00050		0.00000			
EGI		7/4000	0.00175	0.00133	0.00357	ECM	0.00107		0.00000			
Geological insight model												
ECM+EJ+ET+EGI		1/4000	0.00025	0.00025		EW	0.00072		0.00000			
ECM+EJ+ET		1/4000	0.00025	0.00025		EGI	0.00300		0.00000			
ECM		2/4000	0.0005	0.00057		ET	0.00167		0.00000			
ET		2/4000	0.0005	0.00043		EJ	0.00050		0.00000			
ET+EGI		3/4000	0.00075	0.00073		ECM	0.00107		0.00000			
EGI		8/4000	0.002	0.00202								

Summary:

- Fault Models contain geometry and default slip rate values for fault sections.
- Deformation Models contain complete listing of faults with alternative slip rates intended to represent a complete, kinematically consistent model.
- Earthquake rate models for A faults are based on paleoseismic data and slip rates
  - A minimum of three models for each fault are intended to span the range of viable models, additional models are possible for faults with more available geologic data